

# Optical observational biases in the GRB redshift

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**Abstract.** The measured redshifts of gamma-ray bursts (GRBs), which were first detected by the Swift satellite, seem to be bigger on average than the redshifts of GRBs detected by other satellites. We analyzed the redshift distribution of GRBs triggered and observed by different satellites (Swift[1], HETE2[2], BeppoSax, Ulysses). After considering the possible biases significant difference was found at the  $p = 95.70\%$  level in the redshift distributions of GRBs measured by HETE and the Swift.

**Keywords:**  $\gamma$ -ray sources; gamma ray burst; statistical analysis

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## INTRODUCTION

In this paper we extend our work [3] where we compared the redshift data of the GRBs triggered by the Swift and by other non-Swift spacecrafts. In that paper five statistical tests showed  $p \geq 99.40\%$  significance comparing the redshift distributions for the Swift and non-Swift samples between 01/01/2005-31/01/2006, suggesting that the redshifts of the Swift sample are on average larger than that of the non-Swift sample.

Here our data include GRBs between 28/02/1997-03/05/2008 from Greiner's survey (<http://www.mpe.mpg.de/~jcg>). The redshift values are taken from this source, and while  $\log T_{90}$  values are also available we do not use the short-long or the short-intermediate-long grouping [4, 5, 6, 7, 8, 9]. This is beyond the scope of this papers as it would complicate the statistics due to the different satellites' trigger criteria. However, most bursts in our sample come from the long and possibly the intermediate duration group [10, 11, 12].

Note that only satellites triggering GRBs were included here, i.e. we have omitted some interesting results regarding the RHESSI satellite [13, 14].

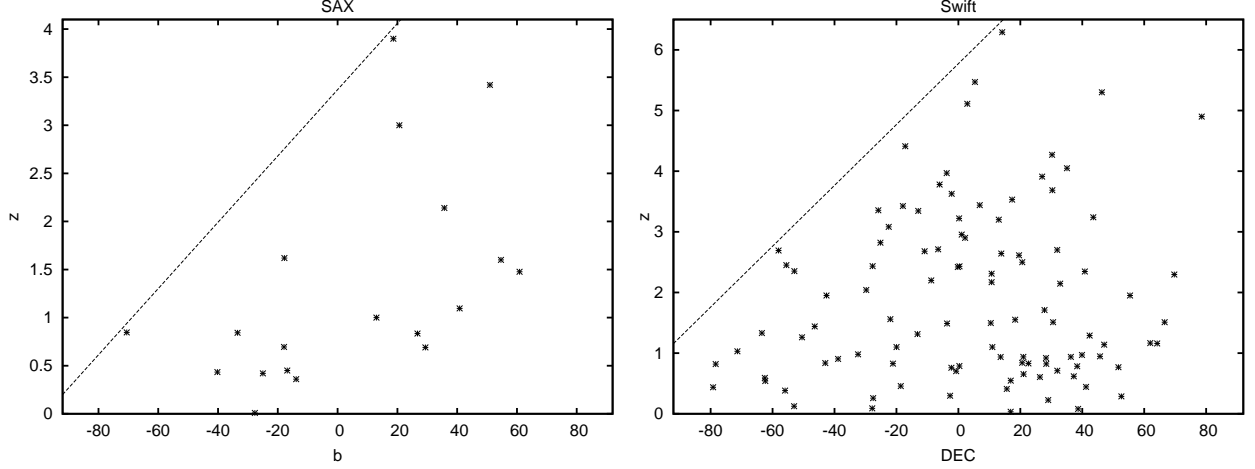
Since the Ulysses, ASM and XTR trio observed a total of 8 GRBs, therefore we aggregated them into one group (labeled Ulysses). The detailed statistics are the following:

Spacecraft	GRB	GRB with $z$	$z_{\min}$	$z_{\max}$
HETE	79	20	0.1606	3.372
SAX	57	19	0.0085	3.9
Swift	315	103	0.0331	6.29
Ulysses group (Ulysses + ASM + XTR)	64	8	0.706	4.5

## BIASES

To compare the  $z$  distributions the Swift and non-Swift samples were compared using non-parametric rank based tests: the Kolmogorov-Smirnov test and the median test. These rank based tests have the clear advantage of being unaffected by any monotonous transformation in the  $z$  values.

The Kolmogorov-Smirnov test compares the maximum difference in the cumulative distributions of the redshifts in the two samples. The median test compares the medians of the Swift and non-Swift samples as follows: be chosen  $N_{\text{Swift}}$  objects randomly from the sample of the non-Swift events ( $N_{\text{Swift}}$  denotes the number of GRBs in the Swift sample), and calculate the median. Repeat this e.g. 100000 times, and these Monte-Carlo simulations give the median



**FIGURE 1.** SAX’s redshift-galactic latitude and and Swift’s redshift-declination distribution. The galactic disk is clearly visible as a void between  $-10 < b < 10$ . There are some signs of the north/south asymmetry, too.

distribution for  $N_{\text{Swift}}$  random GRBs selected from the non-Swift group. Comparing this distribution with the real Swift median  $z$  gives us the significance level for the null hypothesis that the two medians are equal.

The significance of the Kolmogorov-Smirnov and the median test changes as new data arrive continuously from the spacecrafts. The significances show gradual fall till 10/2006, however after the probabilities rise - while the length of the datasets grows! This kind time dependence indicates some fundamental change in the global observational strategy.

There are definite selections effects from satellite lifespan and sky coverage E.g. the Swift’s X-ray afterglow observations revisit the earlier GRB directions and create hot spots in the GRB sky distributions. The optical follow-up observations’ sky coverage is strongly biased too, and it changes from spacecraft to spacecraft. It is due to the different technical limitations, telescope availability and the scientific community interest.

On Fig. 1. we show the non-isotropic redshift distribution of the SAX’s and Swift’s GRBs: both in the galactic and in the equatorial system there are strong selection effects. The galactic disk is clearly visible as a void around  $-10 < b < 10$ , and the clear cutoff in the redshift at low declinations shows that the majority of the optical observations were made on the northern hemisphere.

## RECONSTRUCTION

The observational biases demonstrated in the previous section can be accounted for - the reconstructions are similar to the magnitude limited quasar sample. We used a reconstruction technique based on the Lynden-Bell’s C- method [15], [16] to generate weights from the untruncated part of the data and reconstruct the original (untruncated) density function.

Let sort our bursts in ascending order by  $z$ , and let  $\Omega_i$  be the solid angle where all bursts with  $z < z_i$  can be detected. Here  $\Omega_{i+1} \subseteq \Omega_i$ , which simplifies the analysis.

We construct the real  $n(< z)$  cumulative density function in the following way: let  $N_i = \sum_{j \in \Omega_i} 1$ , i.e. there are  $N_i$  burst within the  $\Omega_i$  region. Here  $n(< z_i)$  is untruncated, hence  $n(< z_{i+1}) = n(< z_i)(N_i + 1)/N_i$ . Starting the sequence with  $n(< z_1) = 1$  we can reconstruct the cumulative density function.

For the  $\Omega_z$  sequences we considered both the  $b$  and declination cuts for each spacecrafts, determined from the real observational data. Fig.2. shows the reconstructed  $n(< z)$  cumulative distribution of the different spacecrafts’ GRB observations. Here the KS test gives  $p = 95.7\%$  for the HETE and Swift distribution.

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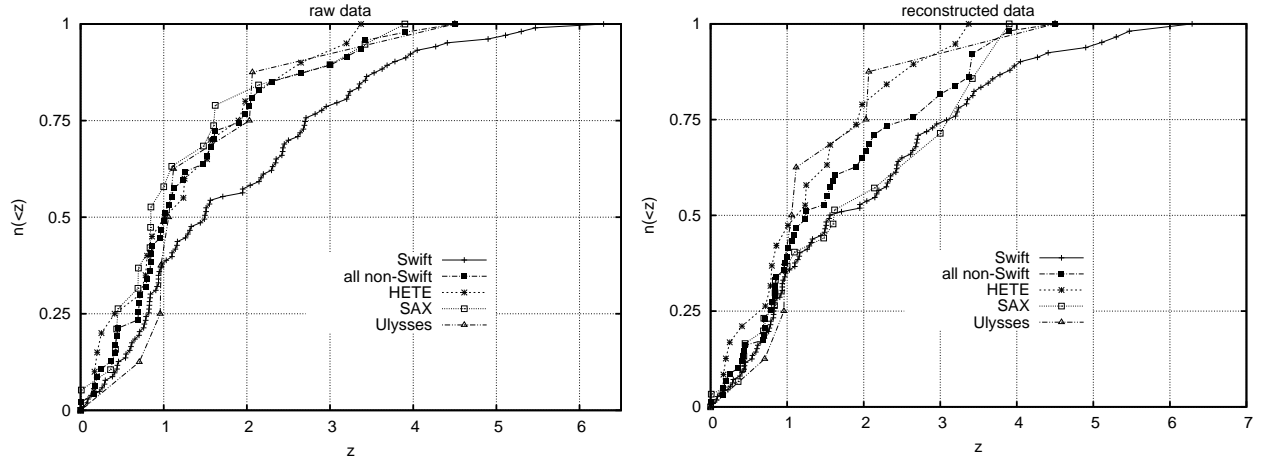


FIGURE 2. The raw  $n(<z)$  cumulative distribution of the different spacecrafts' GRB observations and the reconstructed  $n(<z)$ .

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